Multiple Benefits of Green Roofs

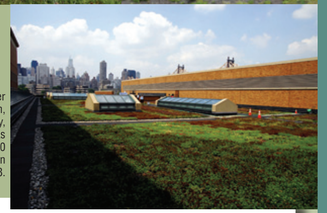
There are significant data demonstrating additional benefits including:

- Urban heat island mitigation
- Thermal insulation with reduced building energy costs
- Stormwater runoff retention
- Increased roof service life
- Biodiversity and ecosystem restoration potential
- Sound insulation
- Increased property amenity

Green Roofs in New York City being monitored by NASA & Columbia University

Regis High School in Manhattan has a large green roof, planted in 2010.

The U.S. Postal Service in Manhattan has the largest green roof (68,000 square feet), planted in 2009.

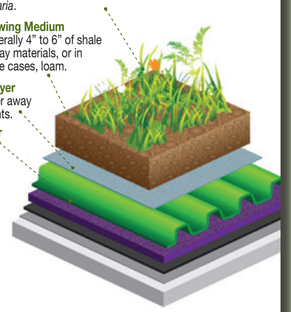


Across the river from Manhattan, in Long Island City, Con Edison has had a 10,000 square foot green roof since 2008.

Social Benefits for Our Cities

Green spaces, and the chance to interact with nature, provide a sense of psychological well-being to city residents. In the tradition of urban parks, green roofs can provide residents with an improved aesthetic quality of life. Many green roof spaces are being designed with seating areas to promote social interaction and a sense of connection among neighbors.

The Making of a Green Roof



A World of Green Roofs

Green roofs were first used in Scandinavia, with the modern design taking hold in Germany in the 1960s. Today, about 10% of German houses have green roofs. In 1997, a City of Munich ordinance mandated the inclusion of vegetation on all flat roofs larger than 100 square meters (about 1,076 square feet). Green roofs are also found on buildings owned by municipalities and companies throughout Germany. Other European cities have also mandated green roofs as part of new construction on flat roof buildings. Basel, Switzerland instituted such regulations in 2002 and is now the world's leader in per capita green roof use. Copenhagen, Denmark passed a similar ordinance in 2010, seeking to add some 53,000 square feet of new green roofs per year.

Green Roofs at NASA Centers

NASA's urban research has been complemented by increased use of green roofs at its Centers. They are now part of buildings at NASA's Jet Propulsion Lab (JPL) in California and Langley Research Center (LaRC) in Virginia. In 2009, NASA received a LEED (Leadership in Energy and Environmental Design) Gold certification from the internationally recognized U.S. Green Building Council at the JPL Flight Projects Facility, the first NASA green roof. The latter was designed to help reduce landscape and overall building water use and provide significant sound and thermal insulation benefits. In 2011, NASA received a LEED Platinum certification (the highest level) for a new headquarters building at LaRC, which includes a green roof and a large number of other energy-saving and environmentally friendly features. NASA is also working toward completing renovations on Building 12 at the Johnson Space Center (JSC) in Houston, to house personnel from several mission support directorates. Renovations include a green roof with more than 67,000 plants. NASA will continue to study and increase the utilization of green roofs at its Centers and facilities.

At the JPL Flight Projects Facility, the green roof is shown over the building's auditorium, providing thermal and soundproofing insulation.

Building 12 of JSC under renovation with initial green roof planting.

Planting of the green roof on Langley Building 2101 began in October 2010.

Green Roofs & NASA's Future

With its decades of experience and commitment to environmental sustainability, NASA is well positioned to continue playing a leading role in understanding climate change and other environmental impacts. Among federal government agencies, NASA is uniquely qualified to implement adaptation strategies such as green roof research and implementation, a major factor considering the coastal location of several NASA Centers and facilities. From green roofs atop buildings in New York and Centers on the East, West and Gulf Coasts, to increasing overall efforts to control stormwater runoff and enhance water retention at its facilities, NASA brings together research and technical capabilities unparalleled by other federal agencies. NASA will continue to lead in providing what amounts to one-stop service and expertise in:

Remote (satellite) sensing and imaging	Computer modeling & environmental forecasting	Climate change expertise	Experience in land use systems	Development of an in-depth guide book to explain the science of green roof technology

Even as it reaches for the stars, NASA will continue its efforts to help to revive an old concept, the green roof, to improve the quality of life on earth.

For More Information, Contact

Merrilee Fellows at 818.393.0754 or email mfellows@nasa.gov

http://www.nasa.gov/offices/emd/home/

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National Aeronautics and Space Administration

NASA & GREEN ROOF RESEARCH

Utilizing New Technologies to Update an Old Concept

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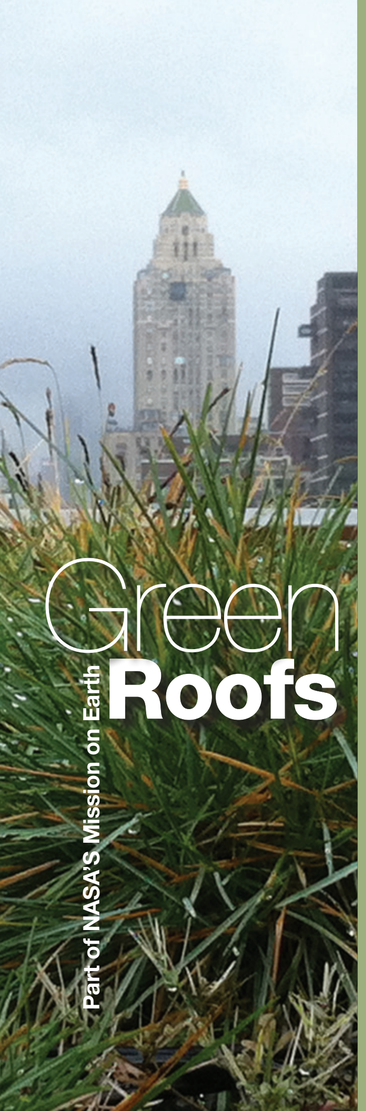


Green Roofs

Part of NASA's Mission on Earth

NASA Utilizes New Technologies to Update an Old Concept

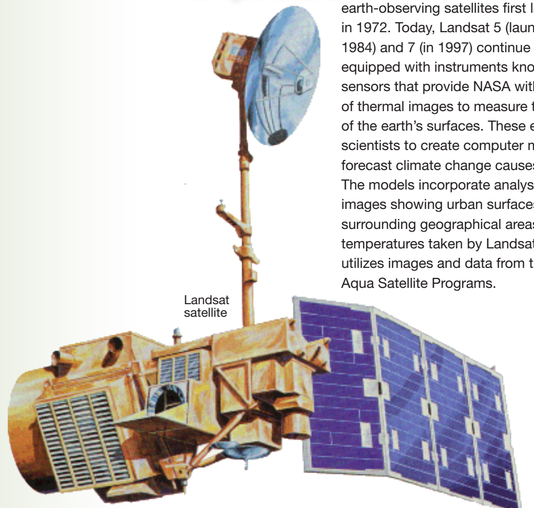
NASA's technology and research promote the exploration of space and play an increasing role in protecting the quality of life on earth. One such example is NASA's effort to address the impacts of climate change and its effect on urban environments, by employing a variety of adaptation strategies to deal with these impacts. A promising strategy involves increased utilization of green (a.k.a. vegetated) roofs, an idea centuries old but with great relevance in addressing today's challenges.

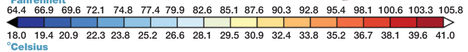
NASA's Goddard Institute for Space Studies (GISS) was established in New York City in 1961 and is a leading center of research on the earth's atmosphere and, increasingly, climate change impacts. For more than a decade, NASA scientists have been working with counterparts from Columbia University, City College and the City of New York to study and address impacts that include increases in sea level rise, coastal erosion and a rise in summer urban surface temperatures. The latter can result in an increase in adverse health effects to vulnerable populations and increased energy costs. Additionally, runoff and overflow from rainstorms into the city's sewer system necessitate increased energy use for sewage treatment. In recent years, much of the research has involved the use of green roofs (as well as light-colored, "high albedo" rooftops) to help mitigate these climate change impacts.

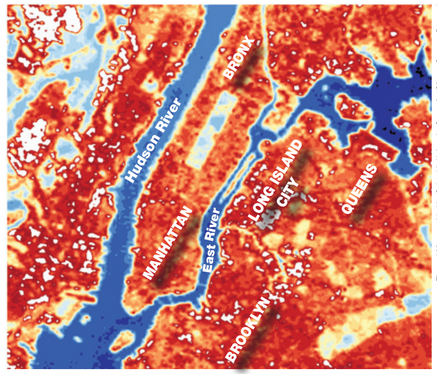
Cover Photos; Upper Right: Queens Botanical Gardens; Lower Left: Con Edison; Lower Right: Regis High School.

Satellites Take the Earth's Temperature

Since 1972, NASA has undertaken three important satellite programs to study the earth's surfaces, its bodies of water, and climates and other factors. Foremost among the collective satellite missions is the Landsat Program, a series of earth-observing satellites first launched in 1972. Today, Landsat 5 (launched in 1984) and 7 (in 1997) continue to operate, equipped with instruments known as remote sensors that provide NASA with thousands of thermal images to measure the temperature of the earth's surfaces. These enable scientists to create computer models to forecast climate change causes and effects. The models incorporate analysis of thermal images showing urban surfaces and surrounding geographical areas and their temperatures taken by Landsat. NASA also utilizes images and data from the Terra and Aqua Satellite Programs.







Thermal Map provided by Columbia University Center for Climate Systems Research

This thermal map, based on an image taken by a Landsat satellite, shows a range of surface temperatures in New York City on a summer's day. The coolest are in blue, the hottest in red. On the graph above, the top line is in Fahrenheit degrees, the bottom in Celsius degrees. Note that the cool spot in the center of the image is the heavily-vegetated Central Park.

Urban Heat Island Effect & Stormwater Runoff

Starting in 2002 scientists from NASA and New York City (NYC) institutions have worked with satellite-generated images and other data to produce maps of surfaces and land cover in urban and surrounding areas. The maps show differences in summer surface temperatures. They helped provide the basis for a 2002 computer model that examined how much of NYC consisted of "impervious" surfaces such as street asphalt, concrete and dark colored roofs (the latter account for about 13% of the NYC land surface area, some 30 square miles citywide).

NASA also looked at grassy and forested areas, and water bodies, in and around the city. Summer surface temperatures in urban areas were shown to be on average, 13-16 degrees Fahrenheit (7.2-8.9 degrees Celsius) warmer than surrounding rural areas, which have more forested and vegetative cover. This phenomenon is known as the Urban Heat Island (UHI) Effect. This results from absorption of the sun's energy by concrete and asphalt street surfaces as well as by dark colored building roofs by day and by tall buildings which keep heat from escaping to the sky at night.

NASA research has found that roofs covered with vegetation – green roofs – provide a cleaner environment and energy savings. NASA conducted its first study in 2003, which showed that UHI effects could be mitigated by substantial green roof utilization. As part of this study, GISS considered various use scenarios for green roof space, ranging from 20% to 50%. The model predicted that extensive use of green roofs could reduce summer surface temperatures by as much as 1.6 degrees Fahrenheit (F).

The NASA study also showed that only 61% of rainwater was treated by the New York City sewage system and that green roofs absorbed 80% of rainfall compared to 2% for standard roofs. A typical green roof, four to six inches deep, can hold one gallon of water per square foot of roof space. Columbia University and NASA researchers have been involved in planting native versions of these vegetated roofs on several types of buildings in New York, to examine the potential long term beneficial effects of large scale green roof utilization.

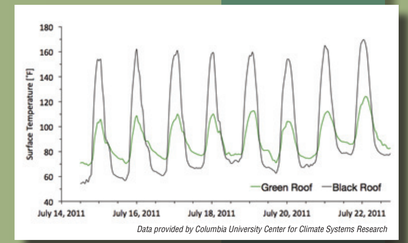
NASA's study also showed peak surface temperatures on NYC rooftops to be on average, 34° F (20° C) warmer than those of green roofs during the day and 14° F (8° C) cooler at night. Indoor summer building temperatures were 4° F cooler for buildings with green roofs.

	Gallons Retained Per Square Foot	Cost to Capture a Gallon	Annual Cost Per Gallon	Cost Per Year Per Square Foot
PlaNYC Stormwater Management Report 2008	0.47	$133.37	$3.33	$1.56
Columbia-NASA Study	10.2	$2.43	$0.02	$0.20

Table provided by Columbia University Center for Climate Systems Research

The chart above is a comparison of green roof studies undertaken by the City of New York (PlaNYC) in 2008 and Columbia University-NASA in 2010. The latter study was based on a year's worth of Green Roof experience at the Con Ed and Fieldston locations. It shows actual estimates for stormwater absorption at much lower costs over the 40 year life of a green roof.

The green roof atop the Con Edison building has been shown to reduce summer surface temperatures (chart at right) while increasing the absorption of stormwater (above).



Data provided by Columbia University Center for Climate Systems Research

The chart above shows much cooler temperatures for green roofs, such as Con Edison, compared with traditional black roofs.